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[Title of the Invention] Optical Scanning Apparatus and Image Forming Apparatus Using the Same

[Claims]

[Claim 1] An optical scanning apparatus, comprising:

light source means;

deflecting means for deflecting a light beam emitted from said light source means; and

a scanning optical system having a plurality of scanning lenses for directing the light beam deflected by said deflecting means onto a surface to be scanned;

wherein of said plurality of scanning lenses, a scanning lens La nearest to the deflecting means is such that the shape thereof in a main scanning cross section is a meniscus shape having positive refractive power, and satisfies a condition that

$d1/fm < 0.06$,

where fm is a focal length of said scanning optical system in the main scanning cross section, and d1 is a central thickness of the scanning lens La, and a scanning lens Lb nearest to the surface to be scanned is such that the shape of a light incidence side surface thereof is an aspherical shape free of an inflection point or an arcuate shape in the main scanning cross section, and satisfies a condition that

$2.5 < |R3/fm|$,

where R3 is a radius of curvature of said light incidence side surface on an optical axis thereof in the main scanning cross section.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

This invention relates to an optical scanning apparatus and an image forming apparatus using the same, and particularly is suitable for an image forming apparatus such as a laser beam printer, a digital copying machine or a multifunction printer having an electrophotographic process which is designed to cause a light beam emitted from light source means to be reflected and deflected by a polygon mirror as a light deflector, and optically scan a surface to be scanned through a scanning optical system to thereby record image information. Also, the present invention relates to a color image forming apparatus using a plurality of optical scanning apparatuses and comprising a plurality of image bearing members corresponding to respective colors.

[0002]

[Prior Art]

Heretofore in the optical scanning apparatus of a laser beam printer or the like, a light beam optically modulated in conformity with an image signal and emitted from light source means has been periodically deflected by a light deflector comprising, for example, a rotary polygon mirror, and has been converged into a spot shape on the surface of a photosensitive recording medium (photosensitive drum) by a scanning optical system (fθ lens system) having an fθ characteristic, and has been optically scanned on the surface of the recording medium to thereby effect image

recording.

[0003]

Fig. 13 of the accompanying drawings is a schematic view of the essential portions of a conventional optical scanning apparatus. In Fig. 13, a divergent light beam emitted from light source means 91 is made into a substantially parallel light beam or a convergent light beam by a collimator lens 92, and this light beam (quantity of light) is shaped by an aperture stop 93 and enters a cylindrical lens 94 having refractive power only in a sub-scanning direction. The light beam which has entered the cylindrical lens 94 emerges in its intact state in a main scanning cross section converges in a sub-scanning cross section and is formed as a substantially linear image near the deflecting surface 95a of a light deflector 95 comprising a rotary polygon mirror.

[0004]

The light beam reflected and deflected by the deflecting surface 95a of the light deflector 95 is then directed onto the surface 98 of a photosensitive drum as a surface to be scanned through a scanning optical system (scanning lens) 96 having an fθ characteristic, and the light deflector 95 is rotated in the direction of arrow A to thereby optically scan the surface 98 of the photosensitive drum in the direction of arrow B (main scanning direction) and effect the recording of image information.

[0005]

[Problem to be Solved by the Invention]

To effect the highly accurate recording of image information in such an optical apparatus, it is necessary that field curvature be well corrected over the entire surface to be scanned, that there be a distortion characteristic (fθ characteristic) accompanied by uniformity of speed between an angle of view θ and an image height Y, and that the spot diameter on the surface to be scanned be uniform at each image height. There have heretofore been proposed various optical scanning apparatus or scanning optical systems satisfying such optical characteristics.

[0006]

Particularly in the case of a color image forming apparatus in which a laser beam is directed from an optical scanning apparatus to four photosensitive members (photosensitive drums) to thereby form latent images thereon, and the images of originals of respective colors, i.e., Y (yellow), M (magenta), C (cyan) and Bk (black) are formed on the surfaces of the respective corresponding photosensitive members, the images of four colors, i.e., Y, M, C and Bk, formed on the surfaces of the respective photosensitive members are superposed on a transferring material such as paper and therefore, if curvature occurs to the scanning line of the optical scanning apparatus corresponding to each photosensitive member, there will arise the problem that an error occurs to the shape of a scanning line among the four colors and color misregistration occurs in the images on the transferring material and this results in the remarkable deterioration of image performance.

[0007]

Several causes of the occurrence of the bending of the scanning line are conceivable, and among them, qualitative description will be made below about a case where the scanning lens is inclinedly mounted.

[0008]

Fig. 14 of the accompanying drawings is a perspective view of essential portions when a flat glass plate 121 is inclined in the scanning optical system (when it is rotated about an axis orthogonal to the optical axis of the scanning lens and the rotation axis of the light deflector), Fig. 15 of the accompanying drawings is a cross-sectional view of the essential portions in the main scanning direction in Fig. 14 (main scanning cross-sectional view), and Fig. 16 of the accompanying drawings is a cross-sectional view of the essential portions in the sub-scanning direction in Fig. 14 (sub-scanning cross-sectional view).

[0009]

An on-axis ray Ai is bent downwardly in the sub-scanning direction by a surface 120, whereafter it emerges in parallelism to an incident light Ai while being shifted by a distance $\Delta Z1$ in the sub-scanning direction. Likewise, the outermost off-axis ray Bi also emerges while being shifted by a distance $\Delta Z2$ in the sub-scanning direction. Assuming here that there is nothing between the flat glass plate 121 and a surface 122 to be scanned, the bending ΔZ of the scanning line on the surface 122 to be scanned is:

$$\Delta Z1 \approx L\cdot\sin(\theta-\mathrm{asin}(\sin\theta/n))$$

$$\Delta Z2 \simeq L\cdot\sin(\theta-\mathrm{asin}(\sin\theta n))/[\cos(\mathrm{asin}(\sin\varphi/n))]$$

$$\Delta Z \simeq \Delta Z2-\Delta Z1 = L\cdot\sin(\theta-\mathrm{asin}(\sin\theta/n)\cdot$$

$$[(1/\cos(\mathrm{asin}(\sin\varphi/n))-1)\cdot$$

(Expression A)

where L is the thickness of the flat glass plate 121, n is the refractive index of the material thereof, θ is the angle of inclination of the flat glass plate, φ is the angle of incidence of an off-axis ray Bi in the main scanning direction.

[0010]

Actually, the scanning lens is of a shape curved in the main scanning direction and has optical power also in the sub-scanning direction and therefore requires a detailed analysis, however when an optical member constituting the scanning optical system is mounted while being rotated about the axis orthogonal to the optical axis of the scanning lens and the rotation axis of the light deflector, there arises the problem that the bending of the scanning line occurs on the surface to be scanned.

[0011]

The present invention has as an object thereof to provide an optical scanning apparatus in which the degree of sensitivity of the bending of a scanning line on a surface to be scanned resulting from the disposition error of a scanning optical system is reduced, whereby good images can always be obtained, and an image forming apparatus using the same. The present invention has as a further object thereof to provide a color image forming apparatus in which there

can be obtained a good color image free of color misregistration.

[0012]

[Means for Solving the Problem]

The optical scanning apparatus of the present invention is an optical scanning apparatus provided with light source means, deflecting means for deflecting a light beam emitted from the light source means, and a scanning optical system having a plurality of scanning lenses for directing the light beam deflected by the deflecting means onto a surface to be scanned, wherein of the plurality of scanning lenses, a first scanning lens nearest to the deflecting means is such that the shape thereof in a main scanning cross section is a meniscus shape having positive refractive power, and satisfies the condition that

$d1/fm < 0.06$,

where fm is the focal length of the scanning optical system in the main scanning cross section, and d1 is the central thickness of the first scanning lens, and a second scanning lens nearest to the surface to be scanned is such that the shape of the light incidence side surface thereof is an aspherical shape free of an inflection point or an arcuate shape in the main scanning cross section, and satisfies the condition that

$2.5 < |R3/fm|$,

where R3 is the radius of curvature of the light incidence side surface on an optical axis thereof in the main scanning cross section.

[0013]

[Embodiments of the Invention]

(First Embodiment)

Fig. 1 is a cross-sectional view (main scanning cross-sectional view) of the essential portions of a first embodiment of the optical scanning apparatus of the present invention in a main scanning direction, and Fig. 2 is a cross-sectional view (sub-scanning cross-sectional view) of the essential portions of the first embodiment of the optical scanning apparatus of the present invention in a sub-scanning direction.

[0014]

Here, the main scanning direction refers to a direction perpendicular to the rotation axis of deflecting means and the optical axis of a scanning optical element (a direction in which a light beam is reflected and deflected (deflected and scanned) by the deflecting means), and the sub-scanning direction refers to a direction parallel to the rotation axis of the deflecting means. Also, the main scanning cross section refers to a plane parallel to the main scanning direction and containing the optical axis of a scanning optical system. Also, the sub-scanning cross section refers to a cross section perpendicular to the main scanning cross section.

[0015]

In Fig. 1, the reference numeral 1 designates light source means, and it is constituted, for example, by a semiconductor laser. The light source means may be

constituted by a semiconductor laser array having a plurality of light-emitting points. The reference numeral 2 denotes an aperture stop which limits a light beam passing therethrough and shapes the shape of the light beam. The reference numeral 3 designates a condensing lens (collimator lens) which converts a light beam emitted from the light source means 1 into a substantially parallel light beam (or a substantially divergent light beam or a substantially convergent light beam). The reference numeral 4 denotes an optical system (cylindrical lens) having predetermined optical power only in the sub-scanning direction, and it causes the light beam passed through the collimator lens 3 to be imaged as a substantially linear image on the deflecting surface (reflecting surface) 5a of a light deflector 5 which will be described later in the sub-scanning cross section. The aperture stop 2, the collimator lens 3 and the cylindrical lens 4 constitutes the elements of an incidence optical system.

[0016]

The reference numeral 5 designates a light deflector as deflecting means, and it is constituted, for example, by a four-side polygon mirror (rotary polygon mirror) and is rotated in the direction of arrow A in Fig. 1 at a constant speed by drive means (not shown) such as a motor.

[0017]

The reference numeral 67 denotes a scanning optical system (fθ lens system) having a condensing function and an fθ characteristic, and having first and second scanning

lenses (fθ lenses) 6 and 7 made of a plastic material.

[0018]

The first scanning lens 6 nearest to the light deflector 5 is such that the shape thereof in the main scanning cross section is a meniscus shape having positive refractive power, and the two surfaces thereof are of a convex shape in the sub-scanning cross section.

[0019]

The second scanning lens 7 nearest to a surface 8 to be scanned is such that the shape of the light incidence side surface thereof is an aspherical free of an inflection point or arcuate shape in the main scanning cross section, and it is a meniscus shape having its concave surface facing the light deflector 5 side and having positive refractive power in the sub-scanning cross section.

[0020]

The scanning optical system 67 causes a light beam based on image information and reflected and deflected by the light deflector 5 to be imaged on the surface 8 of a photosensitive drum as the surface to be scanned, and has an inclination correcting function by establishing a conjugate relation between the deflecting surface 5a of the light deflector 5 and the surface 8 of the photosensitive drum in the sub-scanning cross section.

[0021]

The reference numeral 8 designates a photosensitive drum surface as a surface to be scanned.

[0022]

In the present embodiment, the light beam emitted from the semiconductor laser 1 has its quantity of light limited by the aperture stop 2, is converted into a substantially parallel light beam by the collimator lens 3, and enters the cylindrical lens 4. The substantially parallel light beam which has entered the cylindrical lens 4 emerges in its intact state in the main scanning cross section, converges in the sub-scanning cross section and is imaged as a substantially linear image (a linear image long in the main scanning direction) on the deflecting surface 5a of the light deflector 5. The light beam reflected and deflected by the deflecting surface 5a of the light deflector 5 is then imaged in a spot shape on the surface 8 of the photosensitive drum through the first scanning lens 6 and the second scanning lens 7, and optically scans the surface 8 of the photosensitive drum at a uniform speed in the direction of arrow B (the main scanning direction) by the light deflector 5 being rotated in the direction of arrow A. Thereby, image recording is effected on the surface 8 of the photosensitive drum as a recording medium.

[0023]

The optical arrangement and the surface shapes of the first scanning lens 6 and the second scanning lens 7 in the present embodiment are shown in Tables 1A, 1B and 1C below.

Table 1A (Embodiment)

Construction of Optical Scanning Apparatus		
fθ coefficient, scanning width, Angle of view		
fθ coefficient	k(mm/rad)	149.8
scanning width	W (mm)	214
maximum angle of view	θ (deg)	40.93
wave length, refractive index		
wavelength used	λ (nm)	780
refractive index of fθ lens 6	N1	1.5242
refractive index of fθ lens 7	N2	1.5242
arrangement of scanning optical system		
polygon deflecting surface 5a - lens incidence surface 6a	d0 (mm)	16.50
lens incidence surface 6a - lens exit surface 6b	d1 (mm)	6.00
lens exit surface 6b - lens incidence surface 7a	d2 (mm)	45.50
lens incidence surface 7a - lens exit surface 7b	d3 (mm)	4.00
lens exit surface 7b - surface 8 to be scanned	d4 (mm)	100.85
polygon deflecting surface 5a - surface 8 to be scanned	d total	172.85
angle of incidence (incidence optical system)		
Angle of incidence in main scanning direction	α (deg)	90.00

Table 1B (Embodiment)

Construction of Optical Scanning Apparatus					
meridian line shape of fθ lens 6			sagittal line shape of fθ lens 6		
	incidence surface 6a	exit surface 6b		incidence surface 6a	exit surface 6b
	counter-light source side	counter-light source side		counter-light source side	counter-light source side
R	-3.40747E+01	-2.37094E+01	Rs	1.23654E+02	-3.58307E+01
K	-1.92449E+00	-1.19254E+00	D2	-7.60545E-03	1.94009E-03
B4	3.78594E-06	-1.93521E-06	D4	3.01563E-05	-1.12093E-05
B6	1.78412E-08	1.67602E-08	D6	-4.16484E-08	1.37295E-07
B8	-1.25017E-10	-4.82288E-11	D8	0.00000E+00	-1.54542E-10
B10	1.73294E-13	1.89382E-14	D10	0.00000E+00	0.00000E+00
	Light source side	Light source side		Light source side	Light source side
R	-3.40747E+01	-2.37094E+01	Rs	1.23654E+02	-3.58307E+01
K	-1.92449E+00	-1.19254E+00	D2	-7.60545E-03	1.94009E-03
B4	3.78594E-06	-1.93521E-06	D4	3.01563E-05	-1.12093E-05
B6	1.78412E-8	1.67602E-08	D6	-4.16484E-08	1.37295E-07
B8	-1.25017E-10	-4.82288E-11	D8	0.00000E+00	-1.54542E-10
B10	1.73294E-13	1.89382E-14	D10	0.00000E+00	0.00000E+00

Table 1C (Embodiment)

Construction of Optical Scanning Apparatus					
meridian line shape of fθ lens 7			sagittal line shape of fθ lens 7		
	incidence surface 7a	exit surface 7b		incidence surface 7a	exit surface 7b
	counter-light source side	counter-light source side		counter-light source side	counter-light source side
R	-6.000000E+02	4.50637E+02	Rs	-7.60732E+01	-1.82872E+01
K	0.000000E+00	1.57402E+01	D2	-1.03108E-04	1.49234E-04
B4	0.000000E+00	-1.36218E-06	D4	1.61268E-08	-9.34195E-08
B6	0.000000E+00	3.59567-10	D6	0.00000E+00	2.90104E-11
B8	0.000000E+00	-6.93125E-14	D8	0.00000E+00	-3.68440E-15
B10	0.000000E+00	5.83160E-18	D10	0.00000E+00	0.00000E+00
	Light source side	Light source side		Light source side	Light source Side
R	-6.000000E+02	4.50637E+02	Rs	-7.60732E+01	-1.82872E+01
K	0.000000E+00	1.57402E+01	D2	-9.79758E-05	1.49234E-04
B4	0.000000E+00	-1.36218E-06	D4	1.71428E-08	-9.34195E-08
B6	0.000000E+00	3.59567E-10	D6	0.00000E+00	2.90104E-11
B8	0.000000E+00	-6.93125E-14	D8	0.00000E+00	-3.68440E-15
B10	0.000000E+00	5.83160E-18	D10	0.00000E+00	0.00000E+00

[0025]

The meridian line shapes of the incidence surfaces and exit surfaces of the first scanning lens 6 and the second scanning lens 7 are constituted by aspherical shapes which can be expressed as functions up to the tenth order. For example, when the point of intersection between the first scanning lens 6 and the optical axis is defined as the

origin and the direction of the optical axis is defined as the X-axis and an axis orthogonal to the optical axis in the main scanning cross section is defined as the Y-axis, the meridian line direction corresponding to the main scanning direction is expressed by the expression that

[0026]

[Mathematical Formula 1]

[0027]

$$X = \frac{\frac{Y^2}{R}}{1 + \sqrt{1 - (1 + K)\left(\frac{Y}{R}\right)^2}} + B4 \times Y^4 + B6 \times Y^6 + B8 \times Y^8 + B10 \times Y^{10},$$

where R is the radius of curvature of the meridian line, and K, B4, B6, B8 and B10 are aspherical surface coefficients.

[0028]

Also, the sagittal line direction corresponding to the sub-scanning direction is expressed by the expression that

[0029]

[Mathematical Formula 2]

[0030]

$$S = \frac{\frac{Z^2}{Rs^*}}{1 + \sqrt{1 - \left(\frac{Z}{Rs^*}\right)^2}}.$$

where S is a sagittal line shape defined in a plane containing a normal to the meridian line at each position in the meridian line direction and perpendicular to the main scanning plane.

[0031]

Here, the radius of curvature in the sub-scanning direction (the sagittal line radius of curvature) Rs* at a position distant by Y from the optical axis in the main scanning direction is expressed by the expression that

[0032]

[Mathematical Formula 3]

$$Rs^* = Rs \times (1 + D2 \times Y^2 + D4 \times Y^4 + D6 \times Y^6 + D8 \times Y^8 + D10 \times Y^{10}),$$

[0033]

where Rs is the sagittal line radius of curvature on the optical axis, and D2, D4, D6, D8 and D10 are sagittal line change coefficients.

[0034]

While in the present embodiment, the surface shapes are defined by the above-mentioned mathematical expressions, the scope of the right of the present invention does not limit this.

[0035]

As shown in Tables 1A, 1B and 1C, the incidence surface 6a of the first scanning lens 6 is such that the meridian line shape thereof is an aspherical shape (a non-arcuate shape) and the sagittal line direction thereof is a saddle-shaped surface having convex (positive) power. Also, the exit surface 6b of the first scanning lens 6 is such that the meridian line shape thereof is an aspherical shape (a non-arcuate shape) and the sagittal line direction thereof is a barrel-shaped surface having convex power. The

incidence surface 7a of the second scanning lens 7 is such that the meridian line shape thereof is an arcuate shape and the sagittal line direction thereof is a barrel-shaped surface having concave (negative) power. Also, the exit surface 7b of the second scanning lens 7 is such that the meridian line shape thereof is an aspherical shape which is a concave surface on the optical axis and has an inflection point at an intermediate image height, and the sagittal line direction thereof is a saddle-shaped surface (on the axis) having convex power.

[0036]

As previously described, when the optical member constituting the scanning optical system 67 is mounted while being rotated about the axis orthogonal to the optical axis of the scanning lens and the rotation axis of the light deflector 5, the bending of the scanning line occurs on the surface 8 to be scanned. In the case of a flat glass plate, as shown in the aforementioned expression (A), the bending of the scanning line can be suppressed by making the angle of inclination θ and the thickness L small. A similar tendency is also seen in a scanning lens curved in the main scanning direction.

[0037]

So, in the present embodiment, the central thicknesses d1 and d3 of the first scanning lens 6 and the second scanning lens 7, respectively, are made small to the utmost to thereby reduce the degree of sensitivity of the bending

of the scanning line to optical face tangle error. Particularly, the first scanning lens 6 adjacent to the light deflector 5 is strong in the optical power in the main scanning direction, therefore, the thickness of the first scanning lens 6 is likely to increase. However, by optimizing the power distribution of the first scanning lens 6 and the second scanning lens 7, the disposition of the first scanning lens 6 and the second scanning lens 7, and the aspherical amount of each surface, the first and second scanning lenses 6 and 7 are configured to be thin lenses in which d1 = 6 mm and d3 = 4 mm.

[0038]

Here, letting fm (mm) be the focal length of the scanning optical system 67 in the main scanning cross section and d1 (mm) be the central thickness of the first scanning lens 6, it is preferable to satisfy the condition that

$$d1/fm < 0.06. \quad \ldots (1)$$

By satisfying conditional expression (1), the degree of sensitivity of the bending of the scanning line to optical face tangle error can be reduced. Incidentally, in the present embodiment, d1/fm = 0.04, and this satisfies conditional expression (1).

[0039]

More preferably, conditional expression (1) may be

$$0.02 < d1/fm < 0.05. \quad \ldots (1a)$$

Still more preferably, the lower limit value may be 0.005.

[0040]

Fig. 3 shows the bending of the scanning line on the surface 8 to be scanned when the first scanning lens 6 and the second scanning lens 7 are disposed while being inclined by 3′ about the axis orthogonal to the optical axis of the scanning optical system 67 and the rotation axis of the light deflector 5. As shown in Fig. 3, it will be seen that in spite of the inclination by 3′, the bending is suppressed to 1 μm or less.

[0041]

Fig. 4 shows the bending of the scanning line when the first scanning lens 6 and the second scanning lens 7 are parallel-shifted by 0.03 mm in the sub-scanning direction. Again in this case, it can be seen that as in the above-described case, the bending is suppressed to 1 μm or less.

[0042]

Here, the result of calculating the deviation of the arrival position in the sub-scanning direction on the surface 8 to be scanned when the first scanning lens 6 and the second scanning lens 7 are parallel-shifted in the sub-scanning direction, and dividing the amount of deviation in the sub-scanning direction at each image height by the amount of deviation on the optical axis can be graphed as shown in Fig. 5. Also, it is apparent that the aforementioned values obtained by all scanning lenses 6 and 7 being likewise parallel-shifted by the same amount at a time are the errors of the imaging magnification of the

scanning optical system 67 in the sub-scanning cross section. Consequently, these values are called "the imaging magnification errors in the sub-scanning cross section" of the first and second scanning lenses 6 and 7.

[0043]

That is, it can be seen that if the imaging magnification errors in the sub-scanning cross section of the first and second scanning lenses 6 and 7 is made small, the degree of sensitivity of the bending of the scanning line to the parallel shift in the sub-scanning direction is reduced.

[0044]

In the present embodiment, as shown in Fig. 5, the imaging magnification errors in the sub-scanning cross section are suppressed to 2% or less, and as previously described, a scanning optical system almost free of the occurrence of the bending of the scanning line is achieved. If this value is suppressed to 10% or less, the system can be substantially free of the problem.

[0045]

Also, the values of the imaging magnifications in the sub-scanning cross section relates to the degree of sensitivity of the bending of the scanning line. The smaller the imaging magnification in the sub-scanning cross section is, the less the bending of the scanning line due to the inclination of the rotation axis of the light deflector 5 or the optical face tangle error of the light deflector

itself.

[0046]

That is, in the present embodiment, letting βs be the imaging magnification in the sub-scanning cross section (sub-scanning imaging magnification) of the scanning optical system 6, it is preferable to satisfy the condition that

$|\beta s| < 2.5$ ... (2)

By satisfying conditional expression (2), the degree of sensitivity of the bending of the scanning line can be substantially reduced. Incidentally, in the present embodiment, $|\beta s| = 2.0$, and this satisfies conditional expression (2), to thereby achieve a scanning optical system 6 strong against the optical face tangle error of the light deflector 5.

[0047]

More preferably, conditional expression (2) may be

$0.03 < |\beta s| < 2.2.$ ... (2a)

Still more preferably, the lower limit value may be 0.01.

[0048]

Also, in the present embodiment, as previously described, the shape of the first scanning lens 6 in the sub-scanning cross section is made into a biconvex shape and the shape of the second scanning lens 7 in the sub-scanning cross section is made into a positive meniscus shape having its concave surface facing the light deflector 5 side, whereby a scanning optical system in which the sub-scanning magnification error is 10% or less and the sub-scanning

imaging magnification $|\beta s|$ is 2.5 or less can be set easily.

[0049]

Also, as a feature of the present embodiment, it is preferable that the shape of the incidence surface 7a of the second scanning lens 7 in the main scanning cross section be a gentle aspherical free of any inflection point or arcuate shape, and letting R3 (mm) be the radius of curvature of the incidence surface 7a on the optical axis in the main scanning cross section, the condition that

$$2.5 < |R3/fm| \quad \ldots (3)$$

be satisfied. By satisfying conditional expression (3), the degree of sensitivity of the bending of the scanning line can be reduced. Incidentally, in the present embodiment, $|R3/fm| = 4.00$, and this satisfies conditional expression (3).

[0050]

More preferably, conditional expression (3) may be

$$3.0 < |R3/fm| \quad \ldots (3a)$$

[0051]

Here, for comparison with the present embodiment, the degree of sensitivity of the bending of the scanning line in the case of such a scanning lens in which the incidence side surface of a scanning lens (fθ lens) shown in Fig. 6 and Tables 2A, 2B and 2C below has an inflection point is shown in Figs. 7 and 8. A point which should be particularly noted is that the bending of the scanning line due to the optical face tangle error of the second scanning lens 7 is

W-shaped.

[0052]

Table 2A (Comparative Example)

Construction of Optical Scanning Apparatus		
fθ coefficient, scanning width, Angle of view		
fθ coefficient	k(mm/rad)	150
scanning width	W (mm)	214
maximum angle of view	θ (deg)	40.87
wave length, refractive index		
wavelength used	λ (nm)	780
refractive index of fθ lens 6	N1	1.5242
refractive index of fθ lens 7	N2	1.5242
arrangement of scanning optical system		
polygon deflecting surface 5a - lens incidence surface 6a	d0 (mm)	16.50
lens incidence surface 6a - lens exit surface 6b	d1 (mm)	6.00
lens exit surface 6b - lens incidence surface 7a	d2 (mm)	45.50
lens incidence surface 7a - lens exit surface 7b	d3 (mm)	4.00
lens exit surface 7b - surface 8 to be scanned	d4 (mm)	103.21
polygon deflecting surface 5a - surface 8 to be scanned	d total	174.71
angle of incidence (incidence optical system)		
Angle of incidence in main scanning direction	α (deg)	90.00

Table 2B (Comparative Example)

Construction of Optical Scanning Apparatus					
meridian line shape of fθ lens 6			sagittal line shape of fθ lens 6		
	incidence surface 6a	Exit surface 6b		incidence surface 6a	exit surface 6b
	counter-light source side	counter-light source side		counter-light source side	counter-light source side
R	-3.41949E+01	-2.39290E+01	Rs	8.98781E+01	-4.00000E+01
K	-2.07110E+00	-1.55191E+00	D2	-2.50812E-03	1.50111E-03
B4	4.49022E-06	-3.83595E-06	D4	7.96875E-07	-3.63008E-06
B6	1.50068E-08	1.34064E-08	D6	0.00000E+00	3.32915E-08
B8	-7.93005E-11	-5.49586E-12	D8	0.00000E+00	0.00000E+00
B10	3.65531E-14	-6.54149E-14	D10	0.00000E+00	0.00000E+00
	Light source side	Light source side		Light source side	Light source Side
R	-3.41949E+01	-2.39290E+01	Rs	8.98781E+01	-4.00000E+01
K	-2.07110E+00	-1.55191E+00	D2	-2.50812E-03	1.50111E-03
B4	4.49022E-06	-3.83595E-06	D4	7.96875E-07	-3.63008E-06
B6	1.50068E-08	1.34064E-08	D6	0.00000E+00	3.32915E-08
B8	-7.93005E-11	-5.49586E-12	D8	0.00000E+00	0.00000E+00
B10	3.65531E-14	-6.54149E-14	D10	0.00000E+00	0.00000E+00

Table 2C (Comparative Example)

Construction of Optical Scanning Apparatus					
meridian line shape of fθ lens 7			sagittal line shape of fθ lens 7		
	Incidence surface 7a	exit surface 7b		incidence surface 7a	exit surface 7b
	counter-light source side	counter-light source side		counter-light source side	counter-light source side
R	-2.01401E+02	-6.00000E+02	Rs	-6.64989E+01	-1.78001E+01
K	-2.38821E+00	0.00000E+00	D2	-9.37754E-05	9.98209E-05
B4	1.41111E-06	0.00000E+00	D4	-1.06386E-08	-4.18009-08
B6	-3.88529E-10	0.00000E+00	D6	6.11269E-12	5.37115E-12
B8	6.37890E-14	0.00000E+00	D8	0.00000E+00	0.00000E+00
B10	-4.70592E-18	0.00000E+00	D10	0.00000E+00	0.00000E+00
	Light source side	Light source side		Light source side	Light source side
R	-2.01401E+02	-6.00000E+02	Rs	-6.64989E+01	-1.78001E+01
K	-2.38821E+00	0.00000E+00	D2	-1.19873E-04	9.98209E-05
B4	1.41111E-06	0.00000E+00	D4	1.76029E-08	-4.18009-08
B6	-3.88529E-10	0.00000E+00	D6	-6.55223E-13	5.37115E-12
B8	6.37890E-14	0.00000E+00	D8	0.00000E+00	0.00000E+00
B10	-4.70592E-18	0.00000E+00	D10	0.00000E+00	0.00000E+00

[0053]

When as described above, the shape of the incidence surface 7a of the second scanning lens 7 has an inflection point (W-shape), the bending of the scanning line also becomes W-shaped. The optical scanning apparatus has an adjusting mechanism such as for pushing a portion of the scanning lens in the sub-scanning direction (such as fixing the opposite ends thereof in the main scanning direction, and pushing the center thereof) to correct the bending of the scanning line, however,

the W-shaped bending of the scanning line is difficult to correct for the entire scanning area.

[0054]

Consequently, it is desirable that as in the present embodiment, the shape of the incidence surface 7a of the second scanning lens 7 in the main scanning cross section be a gentle aspherical free of an inflection point or arcuate shape.

[0055]

As described above, in the present embodiment, an optical scanning apparatus can be provided, in which it is difficult for the bending of the scanning line to occur even when the first scanning lens 6 and the second scanning lens 7 are shifted in the sub-scanning direction or inclined due to the manufacturing error, the assembling error or the like as described above, and a reduction in cost by the simplification or disuse of the adjustment of the bending of the scanning line can be expected.

[0056]

(Second Embodiment)

Fig. 9 is a cross-sectional view (main scanning cross-sectional view) of the essential portions of a second embodiment of the optical scanning apparatus of the present invention in the main scanning direction.

[0057]

The difference of the present embodiment from the aforedescribed first embodiment is that the present invention is applied to a tandem type optical scanning apparatus in which light beams emitted from two light source means 1a and 1b scan two surfaces 8a and 8b to be scanned simultaneously through a single light deflector 5. In the other points, the

construction and optical action of the present embodiment are substantially similar to those of the first embodiment, whereby a similar effect is obtained.

[0058]

That is, in the present embodiment, the optical scanning apparatus has scanners A and B disposed symmetrically with respect to the polygon mirror 5. Also, in the present embodiment, the two light beams emitted from the two light source means 1a and 1b are simultaneously reflected and deflected by the adjacent deflecting surfaces 5a and 5b of the polygon mirror (light deflector) 5 having four deflecting surfaces after traveling through aperture stops 2a, 2b, collimator lenses 3a, 3b and cylindrical lenses 4a, 4b, and are imaged on the respective surfaces 8a and 8b of discrete photosensitive drums through the respective scanning optical systems 67a and 67b shown in the first embodiment.

[0059]

Also, in Fig. 9, the reference numeral 9 designates a writing start position detecting lens (BD lens) which condenses a light beam for writing start timing (BD light beam). The reference numeral 25 denotes writing start position detecting means (BD sensor) which obtains a synchronizing signal for determining a scanning start position in a lengthwise direction. The reference numeral 26 designates an aperture stop for synchronism detection, and the reference numeral 27 denotes an electric substrate on which the light source means 1a, 1b and the BD sensor 25 are disposed.

[0060]

In Fig. 9, the light beams emitted from the light source means 1a and 1b and incident onto the deflecting surfaces 5a

and 5b are incident at an angle of 90° with respect to the optical axes of the corresponding scanning optical systems 67a and 67b.

[0061]

(Color Image Forming Apparatus)

Fig. 10 is a schematic view of the essential portions of a color image forming apparatus in which two optical scanning apparatuses, each of which is shown in Fig. 9, are disposed in parallel, and four scanning lines in total are depicted by two light deflectors.

[0062]

In Fig. 10, four light beams reflected and deflected by the polygon mirrors (light deflectors) 5 and 5, and passed through first scanning lenses 16a, 16b, 16c, and 16d are bent downwardly by 90° in Fig. 10 by turn-back mirrors 18a, 18b, 18c, and 18d, and are directed onto the surfaces 8a, 8b, 8c, and 8d of the corresponding drums through second scanning lenses 17a, 17b, 17c, and 17d.

[0063]

By scanning a plurality of light beams by a single polygon mirror as described above, it is possible to eliminate a polygon mirror heretofore required per light beam, thereby achieving the simplification of the entire color image forming apparatus.

[0064]

(Image Forming Apparatus)

Fig. 11 is a cross-sectional view in the sub-scanning direction showing essential portions of an embodiment of the image forming apparatus of the present invention. In Fig. 11, the reference numeral 104 designates the image forming

apparatus. Code data Dc is inputted from an external device 117 such as a personal computer to the image forming apparatus 104. This code data Dc is converted into image data (dot data) Di by a printer controller 111 in the image forming apparatus. The image data Di is inputted to an optical scanning unit 100 having the construction shown in the first embodiment. A light beam 103 modulated in conformity with the image data Di is emitted from the optical scanning unit 100, and the photosensitive surface of a photosensitive drum 101 is scanned in the main scanning direction with the light beam 103.

[0065]

The photosensitive drum 101 which is an electrostatic latent image bearing member (photosensitive member) is clockwisely rotated by a motor 115. By this rotation, the photosensitive surface of the photosensitive drum 101 is moved relative to the light beam 103 in the sub-scanning direction orthogonal to the main scanning direction. Above the photosensitive drum 101, a charging roller 102 for uniformly charging the surface of the photosensitive drum 101 is provided so as to contact with the surface of the photosensitive drum. The light beam 103 with which the optical scanning unit 100 scans is applied to the surface of the photosensitive drum 101 charged by the charging roller 102.

[0066]

As previously described, the light beam 103 is modulated on the basis of the image data Di, and is applied to the surface of the photosensitive drum 101 to thereby form an electrostatic latent image thereon. This electrostatic latent image is developed as a toner image by a developing device 107 disposed so as to contact with the photosensitive drum 101 on

the downstream side of the applied position of the light beam 103 with respect to the direction of rotation of the photosensitive drum 101.

[0067]

The toner image developed by the developing device 107 is transferred onto paper 112 which is a transferring material by a transferring roller 108 disposed below the photosensitive drum 101 so as to be opposed to the photosensitive drum 101. The paper 112 is contained in a paper cassette 109 disposed forwardly (on the right as viewed in Fig. 11) of the photosensitive drum 101, and can also be manually fed. On an end portion of the paper cassette 109, a paper feeding roller 110 is disposed, which feeds the paper 112 in the paper cassette 109 to a transporting path.

[0068]

The paper 112 to which the unfixed toner image has been transferred in the manner described above is further transported to a fixing device disposed rearwardly (on the left as viewed in Fig. 11) of the photosensitive drum 101. The fixing device is constituted by a fixing roller 113 having a fixing heater (not shown) therein, and a pressure roller 114 disposed so as to be brought into pressure contact with the fixing roller 113, and pressurizes and heats the paper 112 transported from a transferring portion by the pressure contact portion between the fixing roller 113 and the pressure roller 114 to thereby fix the unfixed toner image on the paper 112. Delivery rollers 116 are disposed rearwardly of the fixing roller 113 and deliver the paper 112 having had the toner image thereon fixed to the outside of the image forming apparatus.

[0069]

Although not shown in Fig. 11, the printer controller 111 effects not only the conversion of the aforedescribed data, but also the control of various portions in the image forming apparatus including the motor 115, and a polygon motor or the like in the optical scanning unit which will be described later.

[0070]

(Color Image Forming Apparatus)

Fig. 12 is a schematic view of the essential portions of the color image forming apparatus of the present embodiment. This embodiment is a tandem type color image forming apparatus in which four optical scanning apparatuses are juxtaposed and image information is recorded in parallel on the surfaces of photosensitive drums which are image bearing members. In Fig. 12, the reference numeral 60 designates the color image forming apparatus, the reference numerals 11, 12, 13 and 14 denote optical scanning apparatuses each having the construction shown in the first embodiment, the reference numerals 21, 22, 23 and 24 designate photosensitive drums as image bearing members, the reference numerals 31, 32, 33 and 34 denote developing devices, and the reference numeral 51 designates a transporting belt.

[0071]

In Fig. 12, R (red), G (green) and B (blue) color signals are inputted from an external device 52 such as a personal computer to the color image forming apparatus 60. These color signals are converted into C (cyan), M (magenta), Y (yellow) and Bk (black) image data by a printer controller 53 in the color image forming apparatus. These image data are inputted to the optical scanning apparatuses 11, 12, 13 and 14, respectively. Light beams 41, 42, 43 and 44 modulated in conformity with the respective image data are emitted from

these optical scanning apparatuses, and the photosensitive surfaces of the photosensitive drums 21, 22, 23 and 24 are scanned in the main scanning direction with these light beams.

[0072]

In the color image forming apparatus of this embodiment, four optical scanning apparatuses (11, 12, 13 and 14) are juxtaposed and they correspond to the respective colors C (cyan), M (magenta), Y (yellow) and Bk (black), and image signals (image information) are recorded in parallel on the surfaces of the photosensitive drums 21, 22, 23 and 24 to thereby print a color image at a high speed.

[0073]

The color image forming apparatus of this embodiment, as described above, forms latent images of respective colors on the surfaces of the corresponding photosensitive drums 21, 22, 23 and 24 by the four optical scanning apparatuses 11, 12, 13 and 14 by the use of light beams based on the respective image data. Thereafter, they are superimposed and transferred onto a recording material to thereby form a full-color image.

[0074]

As the external device 52, use may be made, for example, of a color image reading apparatus provided with a CCD sensor. In this case, this color image reading apparatus and the color image forming apparatus 60 constitutes a color digital copying machine.

[0075]

[Embodiments of the invention]

While various examples and embodiments of the present invention have been shown and described, those skilled in the art would understand that the gist and scope of the present

invention are not restricted to the particular description and figures herein, but extend to various modifications and changes all described in the appended claims.

[0076]

In the following, exemplary embodiments of the present invention will be listed.

[0077]

[Embodiment 1]

An optical scanning apparatus provided with:

light source means;

deflecting means for deflecting a light beam emitted from said light source means; and

a scanning optical system having a plurality of scanning lenses for directing the light beam deflected by said deflecting means onto a surface to be scanned;

wherein of said plurality of scanning lenses, a scanning lens La nearest to the deflecting means is such that the shape thereof in a main scanning cross section is a meniscus shape having positive refractive power, and satisfies a condition that

$d1/fm < 0.06$,

where fm is a focal length of said scanning optical system in the main scanning cross section, and d1 is a central thickness of the scanning lens La, and a scanning lens Lb nearest to the surface to be scanned is such that the shape of a light incidence side surface thereof is an aspherical shape free of an inflection point or an arcuate shape in the main scanning cross section, and satisfies a condition that

$2.5 < |R3/fm|$,

where R3 is a radius of curvature of said light incidence side

surface on an optical axis thereof in the main scanning cross section.

[0078]

[Embodiment 2]

An optical scanning apparatus according to Embodiment 1, wherein the scanning lens La is such that both surfaces thereof are of a convex shape in a sub-scanning cross section.

[0079]

[Embodiment 3]

An optical scanning apparatus according to Embodiment 1 or 2, which satisfies a condition that

$|\beta s| < 2.5$,

where βs is an imaging magnification of said scanning optical system in a sub-scanning cross section.

[0080]

[Embodiment 4]

An optical scanning apparatus according to Embodiment 1, 2, or 3 wherein the scanning lens Lb is of a meniscus shape having its concave surface facing said deflecting means side in a sub-scanning cross section and having positive refractive power.

[0081]

[Embodiment 5]

An optical scanning apparatus according to any one of Embodiment 1 to 4, wherein said scanning optical system is designed such that the imaging magnification errors of said plurality of scanning lenses in a sub-scanning cross section are 10% or less.

[0082]

[Embodiment 6]

An optical scanning apparatus according to any one of Embodiment 1 to 5, wherein said scanning optical system is constituted by two scanning lenses.

[0083]

[Embodiment 7]

An image forming apparatus having an optical scanning apparatus according to any one of Embodiment 1 to 6, a photosensitive member disposed on said surface to be scanned, a developing device for developing as a toner image an electrostatic latent image formed on said photosensitive member by a light beam scanned by said optical scanning apparatus, a transferring device for transferring the developed toner image to a transferring material, and a fixing device for fixing the transferred toner image on the transferring material.

[0084]

[Embodiment 8]

An image forming apparatus having an optical scanning apparatus according to any one of Embodiment 1 to 6, and a printer controller for converting code data inputted from an external device into an image signal and inputting it to said optical scanning apparatus.

[0085]

[Embodiment 9]

A color image forming apparatus having a plurality of image bearing members disposed on the surface to be scanned of an optical scanning apparatus according to any one of Embodiment 1 to 6 for forming images of different colors.

[0086]

[Embodiment 10]

A color image forming apparatus according to Embodiment 9,

further having a printer controller for converting a color signal inputted from an external device into image data of different colors and inputting the image data to respective optical scanning apparatuses.

[0087]

[Effect of the Invention]

According to the present invention, as previously described, there can be achieved an optical scanning apparatus in which the shapes of scanning lenses constituting a scanning optical system are appropriately set, whereby the degree of sensitivity of the bending of a scanning line on a surface to be scanned to the disposition error of the scanning optical system can be reduced and the simplification of a mechanism for adjusting the bending of the scanning line can be achieved and good images can always be obtained, and an image forming apparatus using the same.

[0088]

Further, there can be achieved a color image forming apparatus using a plurality of optical scanning apparatus described above, wherein a good color image free of color misregistration can be obtained.

[Brief Description of the Drawings]

[Fig. 1] A main scanning cross-sectional view of a first embodiment of the present invention.

[Fig. 2] A sub-scanning cross-sectional view of the first embodiment of the present invention.

[Fig. 3] A diagram showing the degree of sensitivity of the bending of a scanning line to the optical face tangle error in the first embodiment of the present invention.

[Fig. 4] A diagram showing the degree of sensitivity of the bending of the scanning line to the parallel eccentricity in the first embodiment of the present invention.

[Fig. 5] A diagram showing the sub-scanning imaging magnification error in the first embodiment of the present invention.

[Fig. 6] A main scanning cross-sectional view in a comparative embodiment.

[Fig. 7] A diagram showing the degree of sensitivity of the bending of a scanning line to the optical face tangle error in the comparative example.

[Fig. 8] A diagram showing the degree of sensitivity of the bending of the scanning line to the parallel eccentricity in the comparative example.

[Fig. 9] A sub-scanning cross-sectional view showing an embodiment of the image forming apparatus of the present invention.

[Fig. 10] A schematic view of the essential portions of the color image forming apparatus of the present invention.

[Fig. 11] A main scanning cross-sectional view showing an embodiment of the present invention.

[Fig. 12] A sub-scanning cross-sectional view showing the embodiment of the image forming apparatus of the present invention.

[Fig. 13] A perspective view of the essential portions of a conventional optical scanning apparatus.

[Fig. 14] A diagram illustrating the occurrence of the bending of a scanning line caused by the inclination of an optical part.

[Fig. 15] A diagram illustrating the occurrence of the

bending of the scanning line caused by the inclination of the optical part.

[Fig. 16] A diagram illustrating the occurrence of the bending of the scanning line caused by the inclination of the optical part.

[Description of Reference Signs]

1: light source means (semiconductor laser/semiconductor layer array)

1a, 1b: light source means (semiconductor laser)

2, 2a, 2b: aperture stop

3, 3a, 3b: condensing lens (collimator lens)

4, 4a, 4b: optical system (cylindrical lens)

5: deflection means (polygon mirror)

6, 16a, 16b: first scanning lens (fθ lens)

7, 17a, 17b: second scanning lens (fθ lens)

67, 67a, 67b: scanning optical system (fθ lens system)

8, 8a, 8b: surface to be scanned (photosensitive drum surface)

11, 12, 13, 14: optical scanning apparatus

21, 22, 23, 24: image bearing member (photosensitive drum)

31, 32, 33, 34: developing device

41: transferring belt

51: multi-beam laser

52: external device

53: printer controller

60: color image forming apparatus

100: optical scanning apparatus

101: photosensitive drum

102: charging roller

103: light beam

104: image forming apparatus
107: developing apparatus
108: transfer roller
109: paper cassette
110: paper feeding roller
111: printer controller
112: transferring material (paper sheet)
113: fixing roller
114: pressure roller
115: motor
116: discharge roller
117: external device

[Name of the Document] Abstract

[Abstract]

[object] To provide an optical scanning apparatus in which the degree of sensitivity of the bending of a scanning line on a surface to be scanned to the disposition error of a scanning optical system is reduced, whereby good images can always be obtained, and an image forming apparatus using the same.

[Means for Achieving the Object]

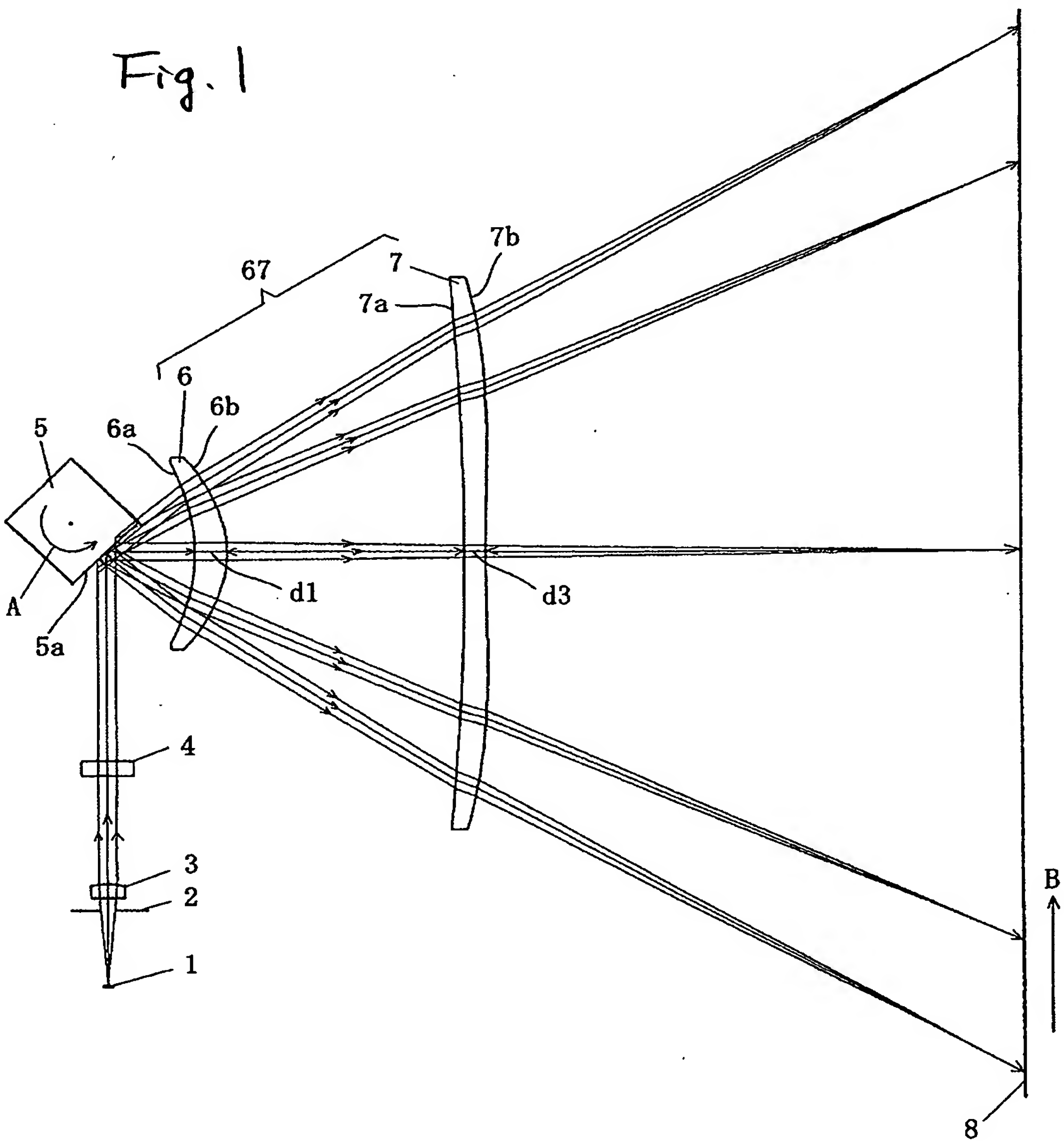
The optical scanning apparatus has deflecting means for deflecting a light beam emitted from light source means, and a scanning optical system having a plurality of scanning lenses for directing the light beam onto the surface to be scanned, and a first scanning lens La is such that the shape thereof in a main scanning cross section is a meniscus shape having positive refractive power, and satisfies the condition that $d1/fm < 0.06$, where fm is the focal length of the scanning optical system in the main scanning cross section, and d1 is the central thickness of the first scanning lens, and a second scanning lens Lb is such that the shape of the light incidence side surface thereof is an aspherical free of an inflection point or arcuate shape in the main scanning cross section, and satisfies the condition that $2.5 < |R3/fm|$, where R3 is the radius of curvature of the light incidence side surface on an optical axis in the main scanning cross section.

[Selected Drawing] Fig. 1

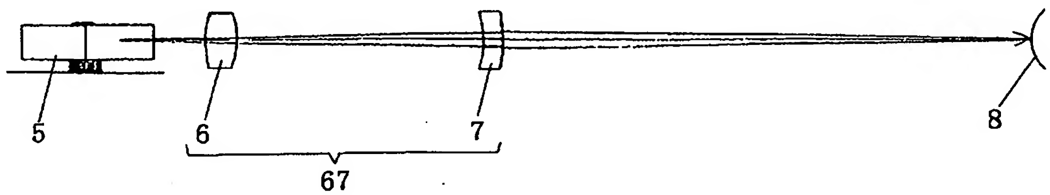
【書類名】　図面

【図１】

Fig. 1



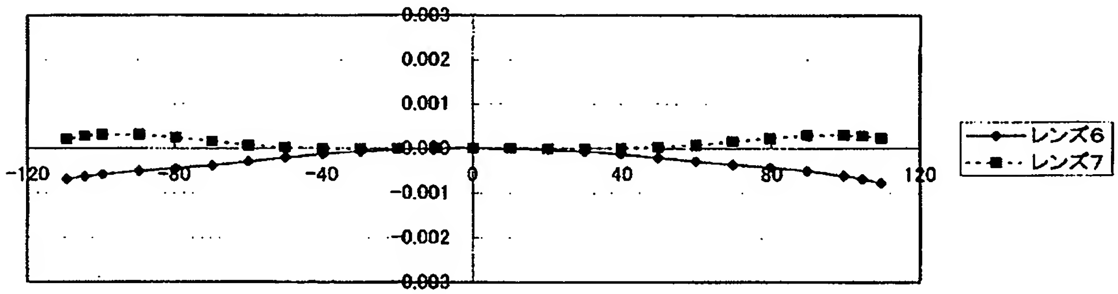
【図２】 Fig. 2



【図３】 Fig. 3

Sensitivity of bending of scaning line (3' tilt)

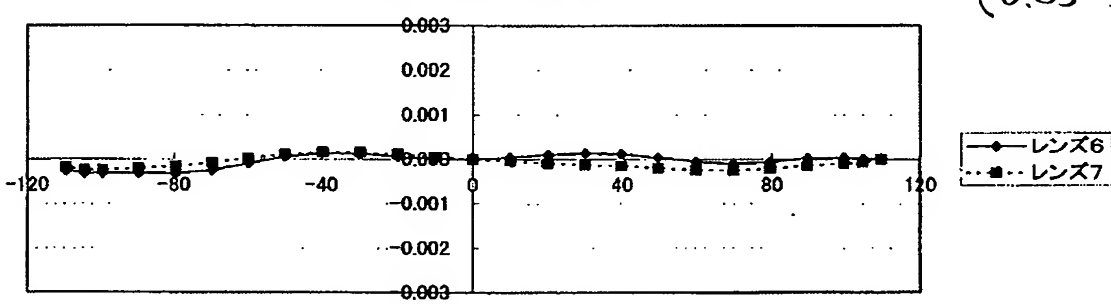
走査線曲がり敏感度(3'チルト)



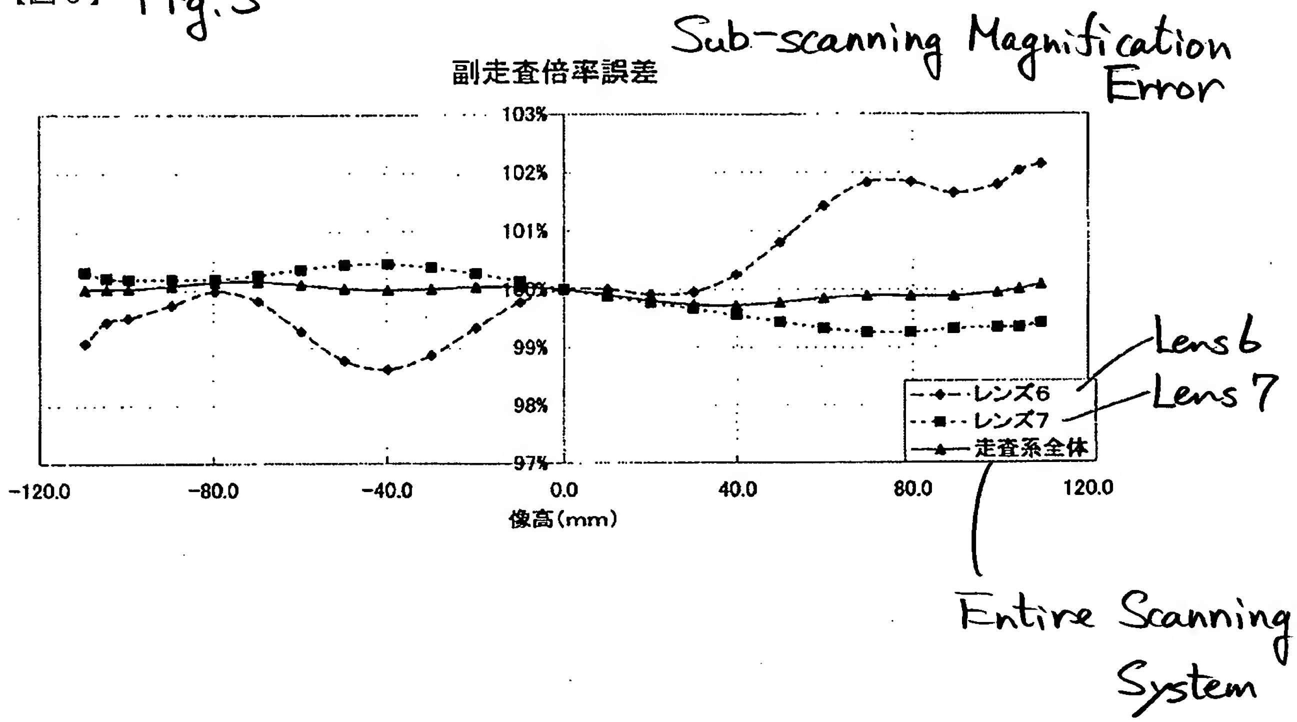
【図４】 Fig. 4

Sensitivity of bending of scaning line (0.03 shift)

走査線曲がり敏感度(0.03シフト)

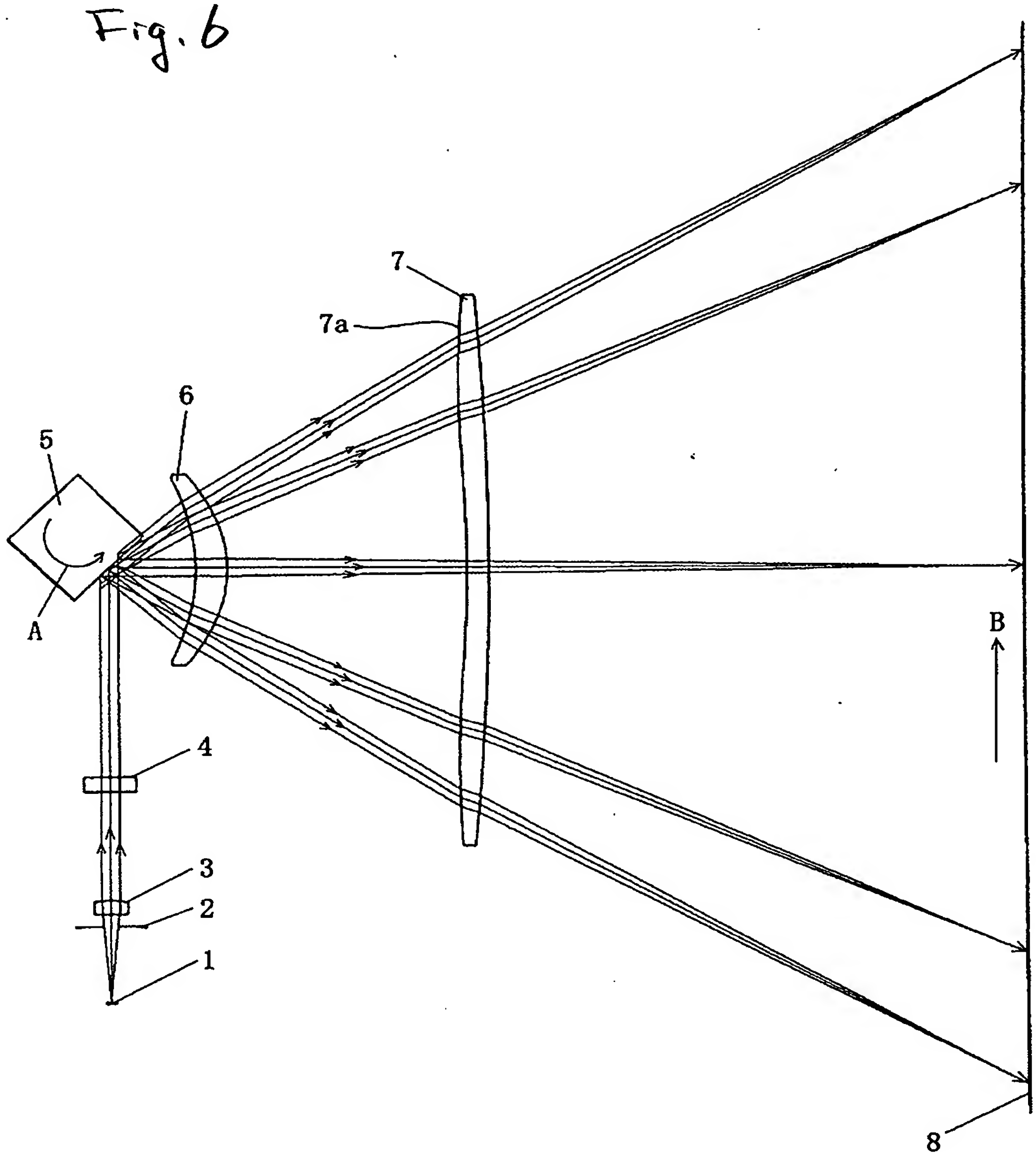


【図５】 Fig. 5

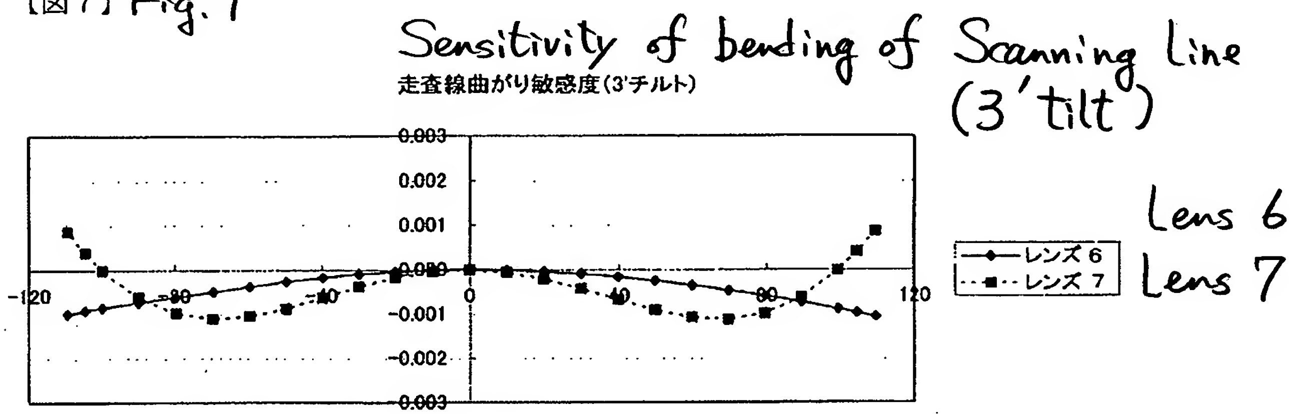

副走査倍率誤差
Sub-scanning Magnification Error
103%
102%
101%
100%
99%
98%
97%
-120.0
-80.0
-40.0
0.0
40.0
80.0
120.0
像高(mm)
レンズ6
レンズ7
走査系全体
Lens 6
Lens 7
Entire Scanning System

【図６】

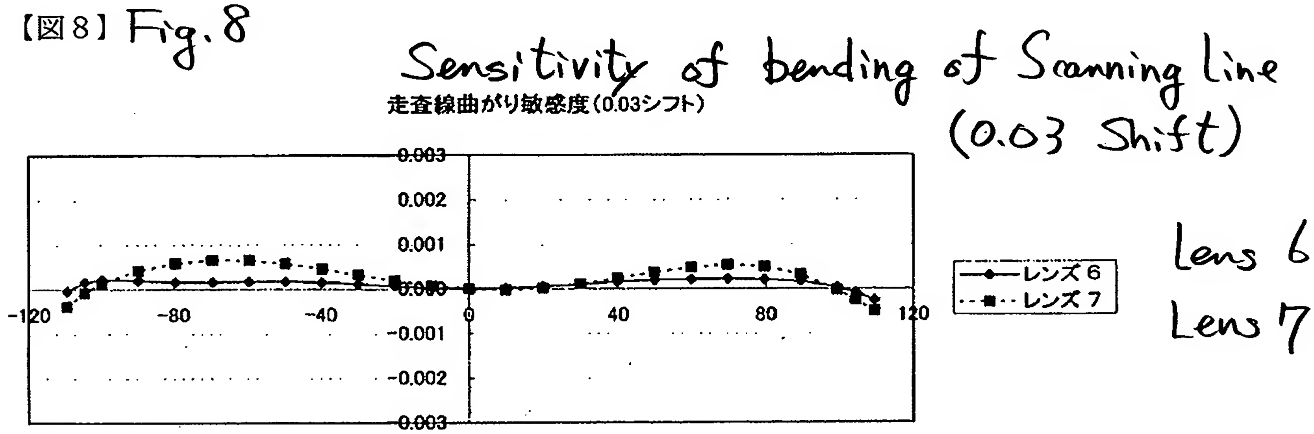
Fig. 6



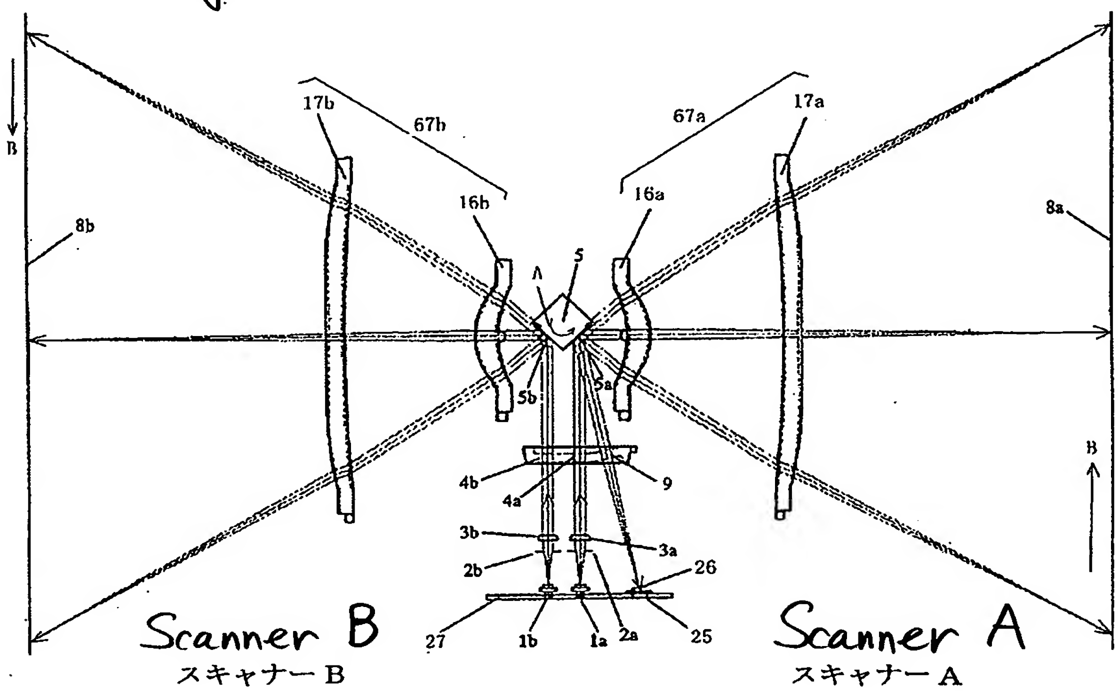
【図７】 Fig. 7



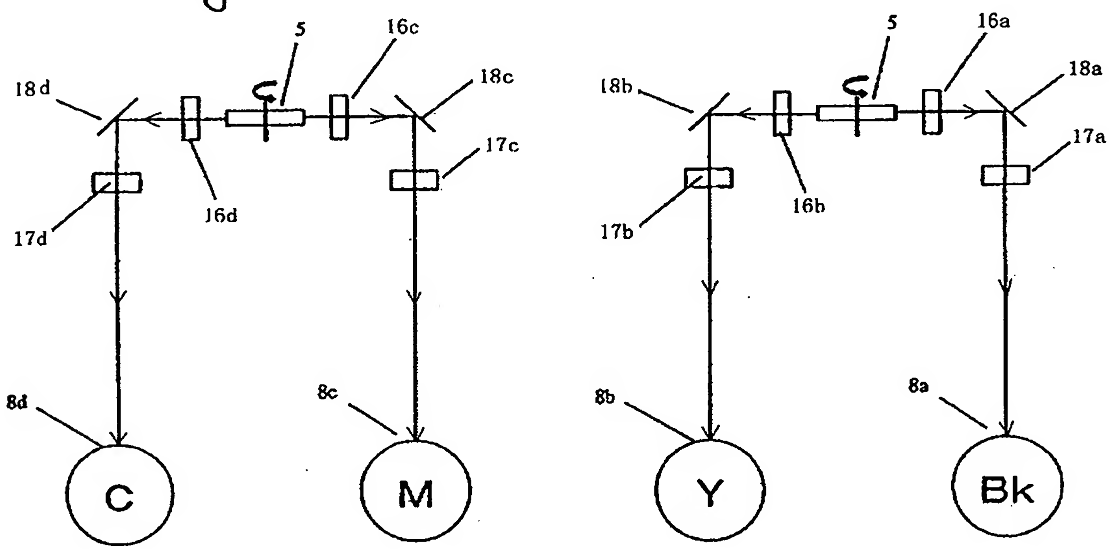
【図８】 Fig. 8



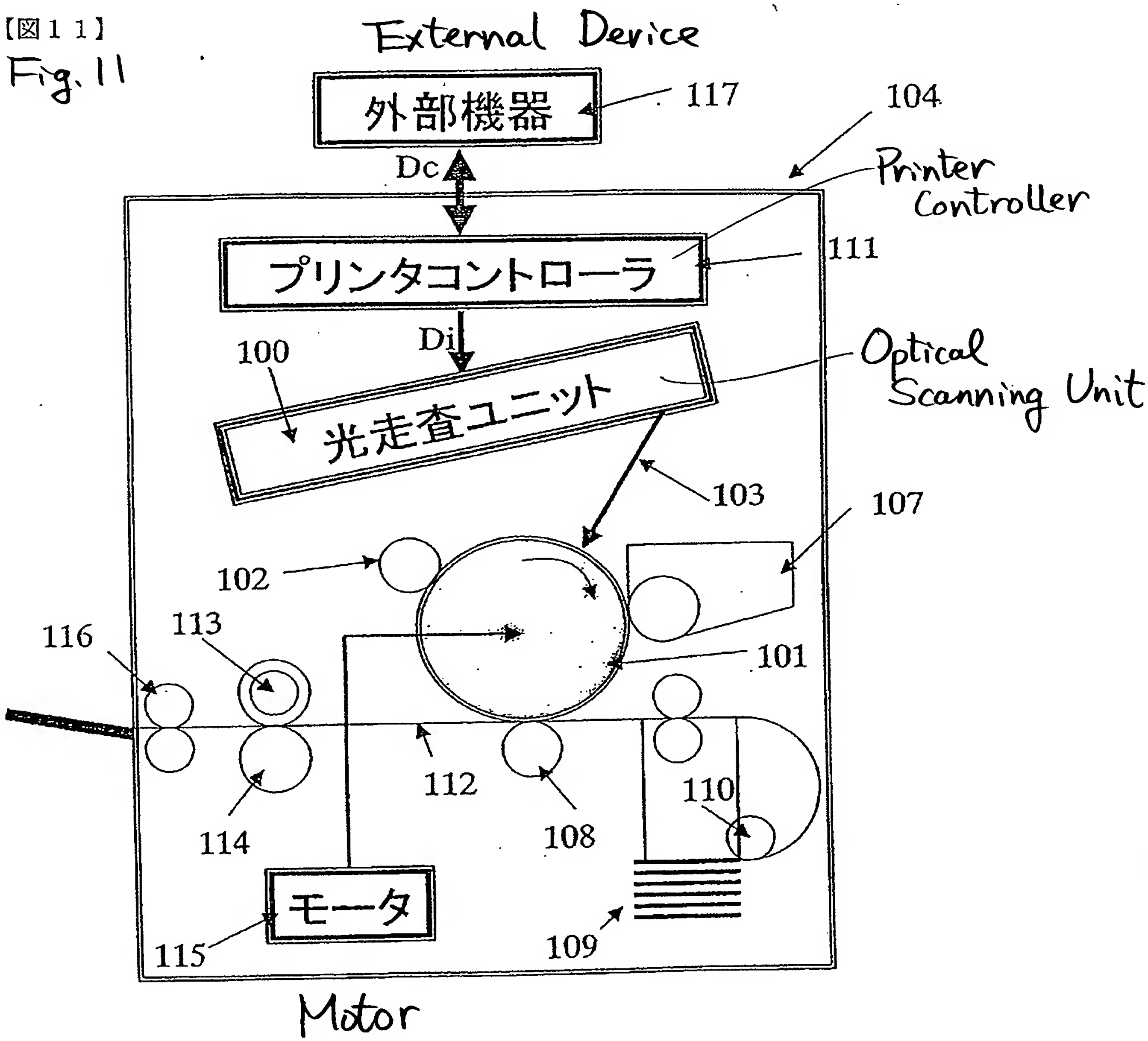
【図９】 Fig. 9



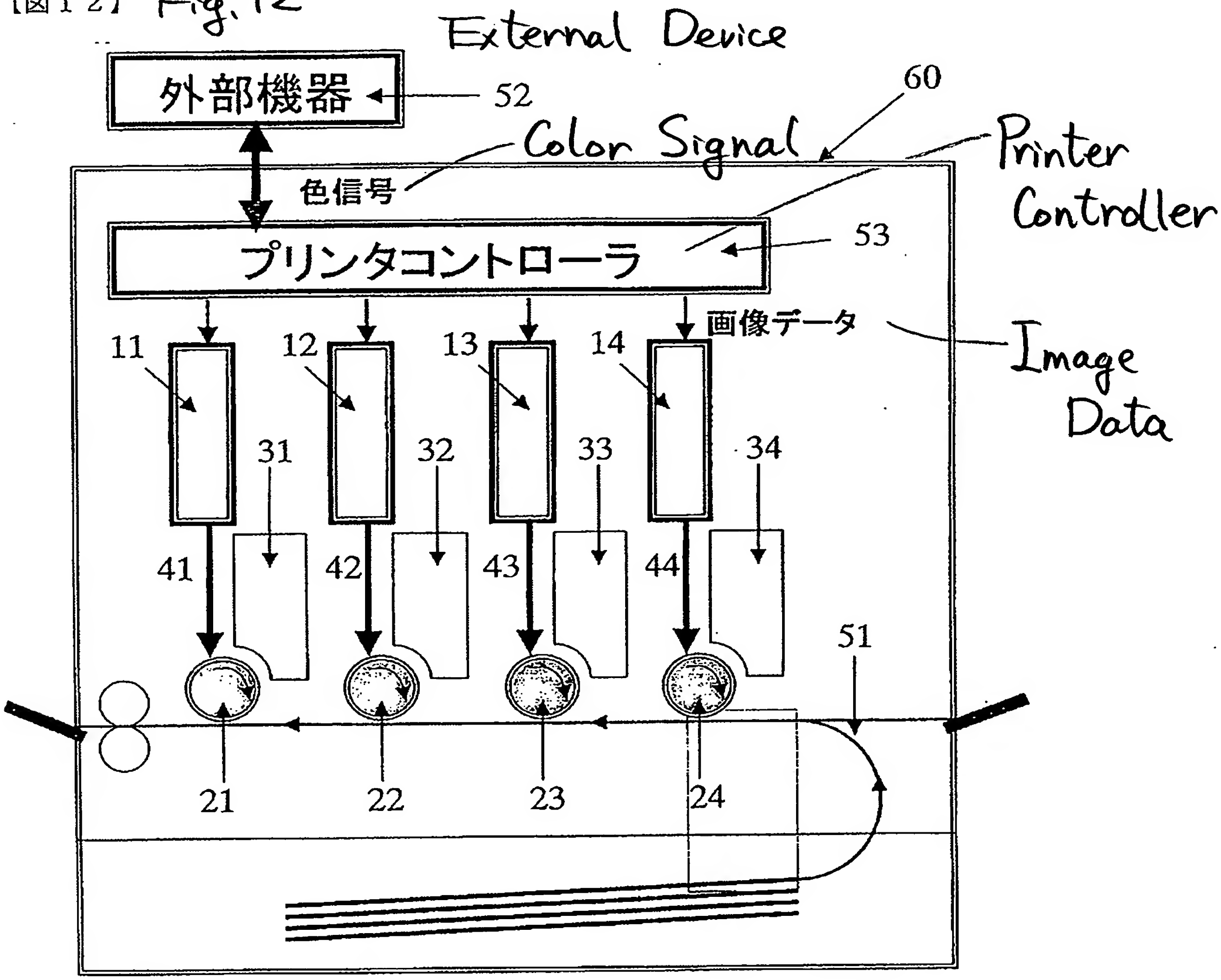
【図１０】 Fig. 10



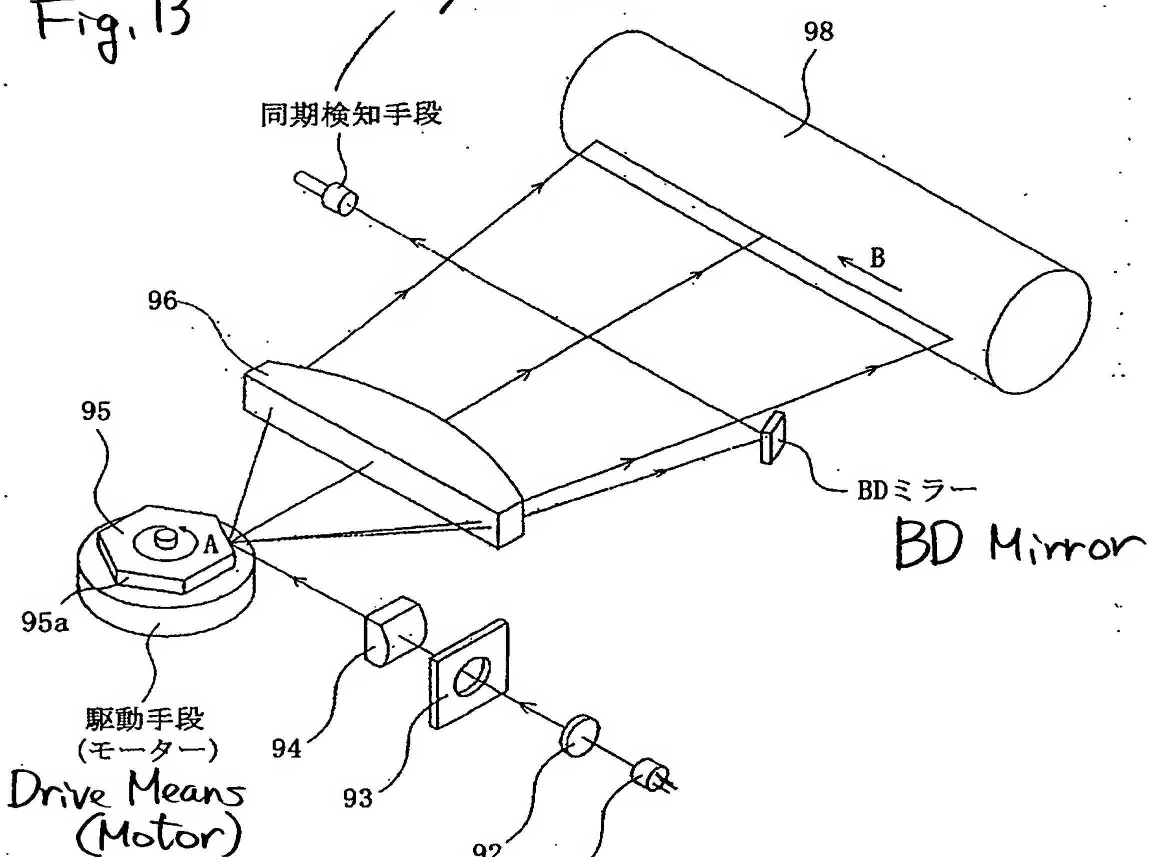
【図１１】
Fig. 11


External Device
外部機器
117
104
Dc
Printer Controller
111
プリンタコントローラ
Di
100
Optical Scanning Unit
光走査ユニット
103
107
102
116
113
101
112
110
114
108
モータ
115
109
Motor

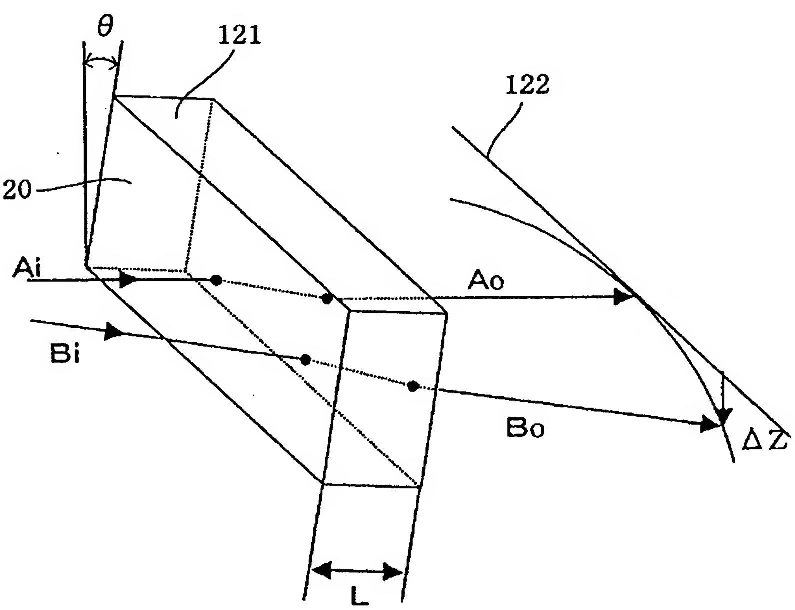
【図１２】 Fig. 12


External Device
外部機器
52
60
Color Signal
色信号
Printer Controller
プリンタコントローラ
53
画像データ
Image Data
11
12
13
14
31
32
33
34
41
42
43
44
51
21
22
23
24

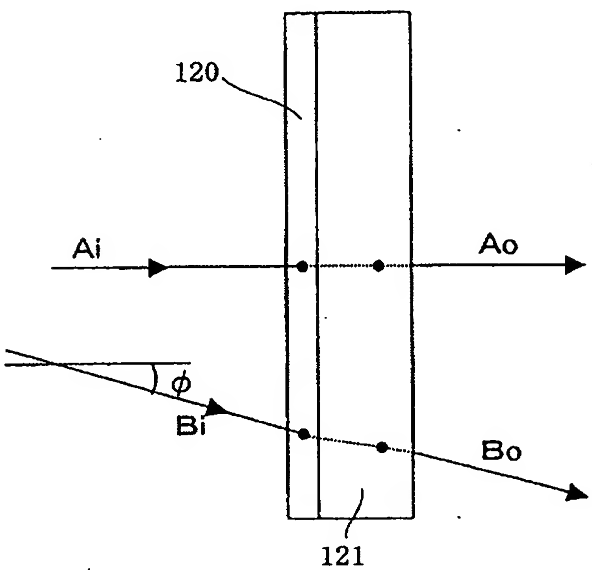
【図１３】
Fig. 13



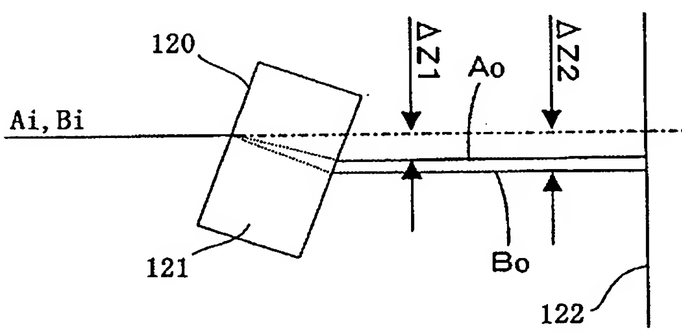
【図１４】 Fig. 14



【図１５】 Fig. 15



【図１６】 Fig. 16



2002-350682

Applicant s Information

Identification No.	[000001007]
1. Date of Change:	August 30, 1990
(Reason of Change)	New Registration
Address:	3-30-2, Shimomaruko, Ohta-ku, Tokyo
Name:	CANON KABUSHIKI KAISHA